as expected, and were unable to pass beyond the glacier alleged to obstruct the Copper or Atna River, about sixty miles from the sea. Meanwhile, a party has actually started, under Gen. Miles's orders, January 30, for the Copper River, consisting of Sergeant Robinson and F. W. Ficket, signal-observer U.S.A., and commanded by Lieut. Allen. They intend to go to the mouth of the Atna or Copper River by steamer, and ascend as far as possible on the ice, pushing on by water as soon as the ice breaks up and the freshets are over. They hope to cross the divide from the Upper Atna, and descend by one of the Yukon tributaries to the mouth of the latter river, and rejoin civilisation at St. Michael's. They may be fortunate enough to make the journey in one season, but are prepared to stay two years. They will add a number of Indians to the party at Sitka, and carry various peace-offerings for the Atna Indians. Lieut. Stoney, of the navy, is reported to have a new expedition nearly organised to continue his investigations of the Kowak River. The plan adopted, so far as yet decided upon, is to take a steam-launch, ascend the river as far as possible, and pursue the explorations to its source, and winter in the region if necessary. It is stated that the party is to be composed of sixteen men, which is dangerously large, considering the limited food-resources of the region, and might be advantageously diminished by one-half for explorations in the interior. If the party were to pass over the divide, and investigate the course of the Colville, returning *viâ* Point Barrow next summer, it would accomplish a praiseworthy and much-needed investigation.

We have received from Messrs. W. and A. K. Johnston a school physical wall map of England and Wales, in which the altitudes above sea-level are shown by varieties of tint. Of its kind this map is good, though we should prefer to see the method of tints combined with the graphic method, in order that pupils may be taught to read the maps with which they have to deal when they become men and women. Accompanying the map is a little hand-book of the physical geography of England and Wales.

THE SCOPE AND METHOD OF PETROGRAPHY[1]

In considering the history of geology we are struck by the fact that towards the close of the last and during the commencement of the present century, when the science was taking rank as an important branch of human knowledge, petrography occupied a much higher position than it has at any subsequent period.

Werner, whose influence was almost unrivalled at the time to which I have referred, was a mineralogist, and his formations were therefore naturally based on the mineralogical characters of the different rocks. His observations were limited for the most part to his own district of Saxony, but he regarded his formations as sediments or precipitates from a universal ocean, and his numerous pupils, fired by his love of science and his intense enthusiasm, rejoiced in extending his classification to the districts with which they were severally acquainted.

The magnificent work of those who devoted special attention to the organic remains in the sedimentary deposits, and especially that of William Smith, the "Father of British Geology," had the effect of deposing petrography from the position which it held under the influence of Werner and his followers. It was clearly shown that the fossil contents of the strata were far more reliable as evidence of chronological relations than their lithological characters, and as soon as this became generally recognised, the reduction of the fossil-bearing rocks all over the world to something like definite order followed as a natural consequence.

The principle that strata may be identified by means of their fossil contents has not only proved applicable to the Secondary and Tertiary formations to which it was originally applied by Smith, Cuvier, and others, but it has been extended by Murchison, Sedgwick, Barrande, and others to the older rocks. Speaking broadly, there can be no doubt that over large areas the succession of the forms of marine life has been remarkably uniform from the Cambrian times down to the present, so that we have in the fossil contents of the different strata by far the most reliable means of determining chronological relations.

It is not surprising, then, that petrography has been comparatively neglected by geologists, for their main object during the present century has been to classify the stratified rocks which form so large a portion of the existing land surfaces.

At the present time, however, we are witnessing a great revival of interest in petrography, not only in this country but all over the globe. This is due in part, no doubt, to the introduction of new methods of research; but it seems to me that there are other and more general causes. The clear recognition of the great principle with which the name of William Smith is so indissolubly united at once made it possible for a host of observers to do excellent work in every quarter of the globe. The interest awakened by the study of the geological structure of the most densely populated regions was akin to that which is felt by the geographical explorer of unknown lands. Until the main features of the geology of fossiliferous regions were described, it was not to be expected that observers would turn aside from a field of research in which they were certain to meet with success for the purpose of attacking problems which, after all, might prove to be insoluble. As time went on, the unexplored tracts in which fossiliferous rocks occur became more and more restricted, or more and more inaccessible, and when the old chaos of Grauwacke fell into order before the brilliant researches of Sedgwick, Murchison, and Barrande, geologists were placed in an entirely new position. They had conquered that portion of the world which was open to their special method of attack. A number of fortresses still held out, it is true, and many of these remain unsubdued at the present day. They will doubtless occupy the attention of those who are most skilled in the old methods of warfare for many years to come. At the same time I think it will be admitted on all hands that the brilliant successes of the old generals have left a large portion of the army with little to do. We must, therefore, look for other worlds to conquer.

Now, on taking a general survey of the subject-matter of geology it will be seen at once that we are profoundly ignorant on questions relating to the origin and sequence of volcanic rocks, the cause or causes of volcanic action, the mode of formation of the crystalline schists, and the origin of mountains. That these questions are really unsolved is proved by the difference of opinion which exists between competent observers. Another point which strikes one is, that if a solution of these problems be ever realised, it will be due in a great measure to the combination of field geology and petrography. This, it seems to me, will explain the great interest which is taken in the latter branch of science at the present day. If I am right in my opinion as to the present state of things, then we may safely predict that petrography will occupy as prominent a position in the immediate future of geology as palæontology has done in the past. In making this statement I trust it will not be thought that I am claiming too high a position for that branch of geology with which I am most intimately acquainted.

Let us turn now to a more detailed consideration of the scope and method of petrography. The rocks of the earth's crust form the subject-matter of the science. Now these may be studied from two more or less distinct points of view—the descriptive and the ætiological. We may set to work to describe the rocks, that is, to ascertain and record every possible fact with regard to them; or we may endeavour to trace the succession of events which has culminated in the state of things which we actually observe. It is perfectly obvious that we cannot hope to attain any considerable success in the second branch of the subject until we have devoted a considerable amount of attention to the first.

Descriptive petrography then concerns itself with the chemical, mineralogical and physical characters of the individual rocks, and also with the distribution and mutual relations of the different varieties. The last-mentioned branch of the subject occupies the same position in petrography as comparative anatomy does in zoology. It may therefore be termed comparative petrography.

When the history of the science comes to be written, it will be recognised that it is to the Germans we are especially indebted for our knowledge of descriptive petrography. The amount of work which has been done in Germany is immeasurably greater than that produced by other nations. For years past they have been steadily improving their methods of observation, as well as observing and recording facts. Moreover, they have been training petrographers who are now scattered all over the world. The Americans especially have availed themselves of the laboratories of Rosenbusch and Zirkel, and almost every Annual Report of the American Survey now bears witness to the influence of

[1] Lecture delivered in the Woodwardian Museum, Cambridge, by J. J. H. Teale, M.A., F.G.S.

Germany from a teaching point of view on the growth of petrographical science. In this sketch, of course, I am only calling attention to the broad facts of history as far as regards the special branch of descriptive petrography. Many observers in France, England, and America have done independent work of the very highest order, and to England especially belongs the credit of having, in the person of Sorby, determined to a very large extent the introduction of the modern methods of microscopical research.

Consider now what is involved in the description of any particular rock, and take, for example, a specimen of the Whin Sill, that mass of basic igneous rock which plays such an important part in the Carboniferous region of the North of England.

The rock is dark gray or bluish-gray when freshly exposed. In texture it varies from compact to coarsely crystalline, the most common variety being one in which the individual constituents are just recognisable by the naked eye. Its specific gravity varies from 2·90 to 2·95. Its chemical composition is shown on this table. (Table referred to.) We have now to consider its mineralogical composition. In the determination of minerals in rocks we use physical and chemical methods. Colour, general appearance, hardness, cleavages, specific gravity, crystalline form, fusibility, and flame coloration are some of the most important physical properties available for the determination of minerals in rocks when they can be examined macroscopically. In thin sections we can use colour, general appearance, cleavages, form, and also the many properties which are brought out by the use of parallel and convergent rays of polarised light. Chemical tests may be applied both to macroscopically recognisable minerals and also to those which can only be observed by the use of thin sections or minute particles and the microscope. The latter are generally referred to as microchemical tests.

By applying these methods, some of which will be more fully explained in the subsequent lectures, we can prove that the rock of the Whin Sill is composed of felspar, pyroxene, titaniferous magnetic iron ore, quartz in the form of grains and also as a constituent of micro-pegmatite, apatite, pyrite, brown hornblende, mica, and some green decomposition products. Apatite, pyrite, hornblende, and mica occur only in very small quantity, and cannot be said to form any appreciable portion of the rock.

In order to give a complete petrographical description, however, it is necessary that we should not only know what minerals are present, but also that we should know the precise composition of each and the relative abundance of the different species. Information on these points can only be obtained by isolating the different constituents of a rock and analysing them separately. Methods of isolation will be described in subsequent lectures. The most important are those which depend on the use of heavy solutions, the magnet and electro-magnet, and various chemical reagents, especially hydrochloric and hydrofluoric acids. The chemical composition of each of the three principal constituents of the Whin Sill is represented on these tables. (Tables referred to.) Now, having obtained a knowledge of the composition of the principal constituents of the rock, it becomes possible to determine with a very fair amount of accuracy the relative proportions of these constituents by calculations based on the bulk analysis of the rock.

There is yet another point of great importance to which attention should be paid in subjecting a rock to an exhaustive examination. Owing to the brilliant researches of Sandberger, it is beginning to be recognised that many of the heavy and so-called rare metals are present in ordinary rocks in minute quantities. Until recently we have been disposed to regard these substances as occurring only in mineral veins and in the deeper portions of the earth from which the mineral veins have been supposed to derive their supply of material. Now it is beginning to be clearly recognised that these substances are very widely distributed even in the superficial crust of the globe. As an illustration of the interest and practical importance of the subject above referred to I may call attention to the important work by Dr. Becker, on the "Geology of the Comstock Lode," recently published by the U.S. Geological Survey. This lode, the yield of which is supposed to have sensibly affected the bullion markets of the world, occurs in a region which is remarkable for the extreme development of igneous rocks (diabase, diorite, andesites, &c.), and for the widespread alteration to which these rocks have been subjected. The bisilicates, especially, have been affected by this alteration, and for immense distances they have been entirely replaced by a green chloritic mineral.

Most careful assays have been executed, under the supervision of Dr. Becker, for the purpose of determining the amount of bullion in the fresh and unaltered rocks, and the relative amounts of gold and silver. He says: "By comparison of the different assays it appears that decomposed diabase carries somewhat less than half as much silver as the fresh rock. When the decomposed rocks are pyritous, the experiments made do not indicate any essential diminution of the gold contents. This fact, however, is quite possibly due to irregularity in distribution and the minuteness of the quantities of gold to be determined. As the decomposition of the rock in question has proceeded at a great depth beneath the surface, it is highly unlikely that silver should have been extracted unaccompanied by gold. Much of the decomposed rock, too, is nearly free from pyrite, and had the gold contents of such specimens been determined, a smaller percentage would probably have been found. The omission [to select specimens free from pyrite] was not detected until it was too late to resume the investigation. So far as quantitative relations are concerned, the silver only can be relied on, though the qualitative detection of gold as well is both interesting and important."

Another point of great interest was determined by Dr. Becker. He isolated the felspar and the augite of the diabase and tested both from silver. He found that for equal weights the augite was eight times as rich as the felspar substance, and as the latter contained some augite, this appears to furnish substantial proo that the silver is a constituent of the augite.

Having subjected a rock to exhaustive chemical and mineralogical examination, it next becomes necessary to compare it with other rocks, and to give it a name. The subject of nomenclature is a very difficult one. It is much to be regretted that notwithstanding all that has been done in descriptive and comparative petrography, we are still far from having any system of classification which is capable of general acceptance. Indeed, we are not agreed as to the first principles on which a classification of rocks should be based. The German petrographers, in most cases, adopt at the outset a principle which we cannot accept. They divide igneous rocks into older and younger: the former including all those which they regard as pre-Tertiary, the latter all those which are of post-Cretaceous age. The division is based, of course, on the assumption that the conditions of eruption in pre-Tertiary times were essentially different from those which have prevailed since. There seems, so far as we can judge, little or no ground for this assumption. The few facts which do at first sight lend support to it appear to be equally capable of explanation on the other hypothesis. The typical pre-Tertiary rocks of the German system are the granites, diorites, gabbros, diabases, and syenites. Now there is reason to believe that these are all plutonic rocks; in other words, that they are the result of slow consolidation beneath the surface, and therefore under great pressure. If this view be correct then their exposure at the surface can only occur long after their formation, and the fact that the majority of those known to us should be of pre-Tertiary age, as Lyell long ago pointed out, need occasion no surprise.

Again, it must be remembered that the mere association of eruptive rocks with pre-Tertiary deposits is no proof in itself that the former are of pre-Tertiary age, and also that many competent observers believe that these are clear cases of Tertiary granite, diorite, diabase, and gabbro.

The igneous rocks, which are regarded by the German petrographers as especially characteristic of the post-Cretaceous period, are the basalts, andesites, trachytes, and rhyolites; in other words, the surface-products of volcanic action. That these should be mainly Tertiary, and that they should differ to a certain extent from their pre-Tertiary equivalents in consequence of alteration, is only what might be naturally expected. This, however, is not sufficient to justify the refusal to give the same name to different specimens of one and the same rock merely because they have been produced at different periods; and the work of Allport, Bonney, Geikie, and others has proved that there are basalts, andesites, and rhyolites of Palæozoic age which are identical in structure, composition, and mode of occurrence with modern rocks.

In the absence of any generally recognised system of nomenclature it becomes difficult to assign a name to the rock of the Whin Sill. It is a holo-crystalline rock composed essentially of plagioclase, pyroxene, titaniferous and magnetic iron ore. In sections the felspar occurs in lath-shaped forms. To such a rock, provided it be of pre-Tertiary age, Rosenbusch would

give the name diabase. We are inclined, on the other hand, to call the rock a dolerite. The important point for the student to remember, however, is that in the present unsettled state of nomenclature his primary duty is to make himself familiar with the structure and composition of the various rock types. The question of names is, after all, only of secondary importance, provided we remember that in looking at the facts through the medium of an unphilosophical nomenclature we may so distort them as to fail to realise their true forms and relations.

Consider now the ætiological aspect of petrography. Most of us are so constituted that we cannot rest satisfied with a mere description of facts ; we almost instinctively endeavour to discover what we call the origin of things. This, after all, merely consists in tracing back as far as possible the chain of events of which the object or phenomenon in question represents the last link. The search after causal relations in the organic world has led to the introduction of a principle which is now recognised as one of the greatest importance in almost every branch of human knowledge. Changes in the characters of organisms are now admitted to be determined by two factors—the inherent properties of the organism and the influence of surrounding circumstances. A very little consideration will serve to show that the changes which occur during and subsequent to the development of minerals and rocks are determined by two allied factors.

Take the case of crystallogenesis. It is not difficult to see in a general kind of way that the characters which a crystal possesses have been determined (1) by the inherent properties of the crystallising substance, and (2) by the influence of surrounding circumstances—of the environment. When we examine thin sections of rocks, furnace-slags, or the refuse products of glass-works, we frequently find a number of bodies which are intermediate as it were between glass and true crystals. These have been carefully examined and admirably described by Hermann Vogelsang, who has also succeeded in producing many of them by artificial means. As they serve to illustrate in a very striking way the principle above referred to, a short description of Vogelsang's experiments will not be out of place.

The crystallising substance finally selected by Vogelsang for the purpose of his experiments was sulphur. This substance is readily soluble in bisulphide of carbon, out of which it crystallises in the rhombic form. If the process of crystallisation be followed under the microscope, nothing definite as to the nature of crystalline growth can be made out. The first objects which appear are definite crystals, and these grow by accretion. If, however, the solution of sulphur be thickened with Canada balsam then, provided the proper proportions of the different substances have been employed, some very interesting phenomena may be observed by the aid of the microscope as the bisulphide of carbon evaporates. Minute fluid spheres arise in the medium and grow by mutual absorption. They finally consolidate as clear, transparent, isotropic bodies, and to them Vogelsang has applied the term globulites. It is impossible to determine absolutely the composition of these globulites, but there seems no reason to doubt the conclusion of Vogelsang that they are portions of the Canada balsam which are richer in sulphur than the surrounding mass, and that they arise in consequence of the attempt of sulphur to crystallise under unfavourable circumstances. Similar bodies may be observed in certain rocks, slags, and blow-pipe beads, although the crystallising compounds must be very different in the different cases.

Under certain circumstances the mass of sulphur and Canada balsam solidifies with the formation of globulites, but under other circumstances additional phenomena may be observed. When the resistance of the medium is too great to prevent the union of the globulites, but not too great to prevent their approach, they become united into various more or less definite forms. The mode of union depends partly on the way in which the globulites attract each other, and partly on the movements in the mass. A linear arrangement of the globulites is very common, and to the form arising in this way Vogelsang has given the name margarite. A rectangular grouping is also not uncommon. From a study of the various forms arising in consequence of the union of globulites, Vogelsang concludes that in the case of sulphur there are in each globulite, as it were, three directions at right angles to each other, in which the attraction is considerable, and that in one of these the attraction is decidedly greater than in the other two.

The building up of the compound forms naturally leaves the surrounding space free from globulites.

Under certain circumstances the globulites become fused, as it were, at the points of contact. This occurs when the resistance is sufficient to prevent the assumption of the spherical form, but not sufficient to resist the destruction of the pellicle at the point of contact. In this way rod-like bodies, termed longulites, arise.

It must be remembered that all these forms are strictly isotropic. They are not, therefore, in any sense of the word, crystals. The moment a true crystal of sulphur appears, it can be recognised by its doubly-refracting properties. They have been termed crystallites, wherever they occur, by Vogelsang, and they evidently arise in consequence of the attempts of some definite chemical compound to crystallise under conditions which do not admit of the free approach of the molecules.

Between crystallites and perfect crystals showing definite external faces there are numerous intermediate forms, such as microlites and skeleton crystals. As further illustrations of the influence of the environment we have only to consider the facts that no two crystals of the same substance are precisely alike in all their characters, and that some substances, like sulphur and carbonate of lime, may be made to crystallise in two different systems by varying the conditions under which the crystallisation is effected.

There can be no doubt, then, that two factor are involved in the determination of the properties which crystals present : the inherent forces of the crystallising substance and the influence of surrounding substances.

So far we have referred only to the birth and growth of crystals. But the history of a crystal does not cease with its formation. With a change in the surrounding circumstances the crystal may be modified or destroyed. Thus we see that crystals have a kind of life-history : they are born, they grow in size by accretion. and finally they cease to exist as distinct individuals.

As an illustration of the influence of a change of physical condition on the character of a crystal, consider the case of leucite. At ordinary temperatures this mineral is generally regarded as tetragonal, and it certainly shows double refraction in thin sections. Klein has shown that by heating leucite to a point far short of its fusibility it may be rendered perfectly isotropic, and hence follows the conclusion that leucite is really isotropic when subject to the conditions under which it is formed. That crystals should be in a state of stable equilibrium, so far as molecular forces are concerned, when subject to the physical conditions under which they are formed, is exactly what we should expect, and that this equilibrium may be disturbed by a change in these conditions is also very easy to understand.

As further illustrations of the principle here referred to, consider the various cases of paramorphosis, such as the change from arragonite to calcite, or from calcite to arragonite ; or, again, the corresponding changes in sulphur.

Illustrations of the changes which arise in crystals in consequence of changes in the chemical conditions to which they are subjected, need not here be referred to in detail ; the destruction of crystalline rocks by denudation is of course a consequence of these changes.

Consider, now, the rocks of which the earth's crust is composed. They also have a life-history. They are formed and destroyed, and it is the business of the petrographer not only to describe and classify them, but also to trace out the cycle of change. For the purpose of illustrating this branch of petrography let us consider certain facts with reference to the genesis of crystalline igneous rocks. It will be admitted on all hands that such rocks as granite, syenite, diabase, rhyolite, trachyte, andesite, and basalt have originated by the consolidation of an intensely heated silicate-magma under different conditions as to temperature and pressure. The consolidation has been accompanied—except in those cases where the magma has consolidated as a homogeneous glass, and these will be left out of account for the present—by the development of crystals. If, then, we would understand the manner in which crystalline igneous rocks have been formed, we must consider the subject of crystallogenesis in silicate-magmas. Numberless facts which need not here be referred to prove that the process of consolidation is not a sudden one. As the surrounding circumstances (environment) become more and more favourable to crystallisation, the minerals separate out one after the other, and at last the whole mass becomes solid, and the rock is formed. The temperature at which any given mineral forms is not determined by its own fusibility. The laws of the formation of minerals in

igneous rocks are analogous to those which determine the formation of salts from concentrated aqueous solutions. Cooling influences the separation of the different minerals only in so far as it affects the solubility of the constituents of the minerals in the silicate-magma. The point at which a mineral forms from a silicate solution has, then, no more connection with its fusibility than the point at which graphite forms in molten iron has with *its* fusibility.

Another point of very great importance is this: the differentiation of crystals in an originally homogeneous magma must necessarily be accompanied by a variation in the composition of that magma. It becomes, then, of great interest to determine the general order of the formation of crystals in igneous magmas. On this subject we have a most valuable and suggestive paper by Rosenbusch, entitled "Ueber das Wesen der körnigen und porphyrischen Structur bei Massengesteinen" (*Neues Jahrbuch*, 1882, ii. p. 1). Before proceeding to give an account of the portion of this paper which bears more particularly on the subject we are now discussing, it may be well to call attention to the methods available for the purpose of determining the order of the formation of the minerals in a rock. There are two. In the first place we may observe the phenomena of inclusions, and in the second place we may observe the extent to which crystalline form has been developed. If one mineral is seen to be included in another, then we may safely infer, subject to certain precautions, that the included mineral is the earlier of the two, and if one mineral shows a more perfect form than another with which it is associated, then we may infer—again subject to certain precautions—that the mineral with the more perfect form is the earlier.

Now in the paper above referred to, Rosenbusch divides the constituents of igneous rocks into four groups:—

(1) The ores and accessory constituents (magnetite, hematite, ilmenite, apatite, zircon, spinel, sphene).

(2) The ferro-magnesian silicates (biotite, amphibole, pyroxene, olivine).

(3) The felspathic constituents (felspar, nepheline, leucite, melilite, sodalite, haüyn).

(4) Free quartz.

He then calls attention to the contrast which is presented by the granites and syenites on the one hand, and the diabases on the other. In the former the following law is adhered to with a very great amount of persistence:—The order of formation is that of increasing basicity: the ores and accessory constituents are first formed, and the quartz is the final product of consolidation. In the diabases and gabbros there is apparently an exception to this law of increasing basicity, the augite consolidating after the felspar. Rosenbusch proposes to divide the granular holo-crystalline rocks into two classes: (1) those in which the minerals of the 2nd group in the above classification consolidate before those of the 3rd, and (2) those in which the reverse relation holds. He then calls attention to cases illustrative of the law of increasing basicity which are furnished by the order of separation in the individual groups. Thus in the ferro-magnesian group, olivine is older than biotite, amphibole and pyroxene; and biotite is older than the bisilicates. In the felspathic group triclinic felspars are older than monoclinic [there are exceptions to this rule, as, for instance, in the porphyroid of Mairus in the Ardennes, where orthoclase crystals are seen to be surrounded by a narrow zone of oligoclase], and the basic triclinic felspars are older than those which contain a large percentage of silica.

The views of Rosenbusch are based on the assumption that the order of formation of crystals in igneous magmas is determined solely by chemical conditions. That these conditions are the more potent seems quite clear, but there are facts which appear to show that physical conditions are not altogether without influence on the result.

The law of increasing basicity may be accepted without hesitation as expressing in a general way the truth as regards the order of separation of the different constituents of igneous rocks.

Now a very interesting conclusion follows as a natural consequence of this law. The effect of progressive crystallisation in a magma must be to increase the percentage of silica, to decrease the amount of lime, iron, and magnesia, to increase the total amount of alkalies, and to increase the potash relatively to the soda in the part which remains liquid. It is always satisfactory to find independent evidence confirmatory of any conclusion at which one may have arrived. Now I think we have confirmatory evidence of this kind in the present case. It will be admitted on all hands that the crystals in porphyritic rocks, such as hypersthene-andesite, have been formed in a magma the composition of which is represented by the bulk analysis of the rock. If, then, we compare the bulk analysis with the analysis of the ground-mass deprived of its crystals, we ought to find confirmation of the above conclusion.

Dr. Petersen has isolated and analysed the ground-masses of two of the Cheviot porphyritic rocks, and by comparing these with the bulk analyses of the rock the truth of the conclusion is most strikingly illustrated. The effect of progressive crystallisation in the andesitic magma has led unquestionably to an increase in the amount of silica, a decrease in the amounts of lime, iron, and magnesia, an increase in the amount of alkalies generally, and an increase in the potash relatively to the soda. In the rock itself soda is in excess of potash; in the ground-mass potash is in excess of soda.

There is yet another piece of independent confirmatory evidence. Every geologist is familiar with the phenomenon of contemporaneous veins. The general view held with regard to them is that they represent portions of material which remained fluid after consolidation had progressed to a considerable extent. If this view be correct, then they should hold the same chemical relation to the main mass of the rock as the ground-mass of the Cheviot andesite does to the main mass of the andesite. Mr. Waller has recently analysed certain contemporaneous veins which occur in the bronzite-diabase of Penmænmawr. He finds that they contain about 7 per cent. more silica than the normal rock, less lime and magnesia, more alkalies, and more potash than soda, although in the normal rock soda is in excess. Contemporaneous veins in the Rowley rag dolerite have also been investigated by Mr. Waller, with the same result as far as increase in silica and total alkalies is concerned. The relation of potash to soda has not yet been determined.

I believe it is admitted to be a general rule that contemporaneous veins contain more silica than the rock with which they are associated. It will be seen that there is abundant evidence of an independent character to confirm the general truth of the conclusion which follows from a consideration of the facts brought forward by Rosenbusch.

I should not have treated this subject at such length did it not appear to have an important bearing on the origin and sequence of volcanic rocks. I can best explain this by referring to the Cheviot district, with which I am slightly acquainted.

Andesitic lavas and tuffs cover large tracts of this district. These are unquestionably the products of surface volcanic action. In the central portion of the volcanic area there is a mass of augitic granite. A consideration of the mineralogical composition of this granite shows that it cannot belong to the acid group of rocks, and this conclusion is confirmed by an examination of the chemical composition of allied rocks from the Vosges. So far as we can judge in the absence of analyses there appears to be a very close connection between the composition of the plutonic and that of the volcanic rocks of the Cheviot district, and we therefore seem justified in concluding that the plutonic masses differ in character from the andesitic lavas merely in consequence of differences in the conditions of consolidation. The plutonic rocks represent the consolidation of the andesitic magma beneath the surface, and therefore under great pressure; the lavas and tuffs represent the consolidation of the same magma at the surface.

I now come to the point to which I wish to direct special attention. The andesitic lavas and tuffs are traversed by quartz-felsite dykes in such a way as to show that a magma of rhyolitic composition must have been erupted by the Cheviot volcanoes subsequently to the period characterised by the eruption of the andesitic magma. Contemporaneous veins similar in character to the quartz-felsite dykes also occur in the plutonic rocks. Again, an analysis of one of the quartz-felsite dykes by Mr. Waller agrees almost exactly with the analyses of the ground-mass of the hypersthene-andesite by Dr. Petersen.

Putting all these facts together, we conclude that the eruption of an andesitic magma was followed, in the history of the Cheviot volcanoes, by that of a rhyolitic magma in consequence of progressive crystallisation in the deep-seated plutonic source. The rhyolitic magma is, so to speak, the mother liquor out of which various basic minerals have crystallised. Suppose a half-consolidated plutonic mass, originally of andesitic composition, to become subjected to a powerful crush such as that which unquestionably arises in the earth's crust under certain circumstances. The mother liquor will be squeezed out of the mass,

like whey out of cheese, and it may finally consolidate as contemporaneous veins in the plutonic rock, as dykes in the surrounding volcanic rocks, or as rhyolitic lavas and tuffs at the surface. The ideas here thrown out appear to me to be capable of extension to other volcanic regions; but as the sequence in these regions is generally complicated by the coming in of basic rocks during the later phases of volcanic activity, it will not be advisable to enter more fully into the subject on the present occasion.

The special characters which igneous rocks present, then, are to be traced to the chemical and physical properties of the original magma and to the influence of surrounding circumstances. Rocks, like minerals, are in a state of stable equilibrium when subjected to the conditions of their formation. When subjected to other conditions, whether physical or chemical, they usually undergo a change. The destruction and disintegration of igneous rocks by the various agents of denudation are familiar to every student of geology, and need not therefore be described on the present occasion.

I trust I have now said sufficient to show that the science of petrography is one of the greatest importance to the geologist of the present day. The remarks on ætiological petrography are, of course, only intended to illustrate the nature of this branch of the subject, and to show that conclusions of the greatest theoretical interest may be expected to follow from a careful consideration of the facts acquired by work in the other branch of the science.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

CAMBRIDGE.—A Report recently issued gives particulars of the successful raising of the roof of the Mineralogical Museum to form a Morphological Laboratory on the new floor thus created. The firm of builders who had furnished estimates ultimately declined the work, and the Department of Mechanism undertook it. Under the continual superintendence of Prof. Stuart and Mr. Lyon the work was so skilfully done that not a crack was occasioned in the ceiling of the Mineralogical Museum, and the deflection of the new timbers was so well calculated that no timber moved upwards or downwards more than the eighth of an inch when the load came upon it. The cost was several hundred pounds less than the estimate. The roof raised was 110 feet long, and the weight fifty tons. A special vote of thanks is to be given to the Department of Mechanism for the care, skill, and economy with which the building operations were conducted.

The Botanical Laboratory has cost a little over 800*l.*; the Morphological Laboratory has cost about 2500*l.*

In the Natural Science "Special" Examinations for the ordinary B.A. degree during the past year, the great majority of candidates chose Chemistry, and showed that they had bestowed considerable pains on laboratory work while yet they were only imperfectly acquainted with the *rationale* of the processes they employed. The candidates in Botany had neglected systematic, and especially descriptive, botany. In June the descriptions of easy, well-marked specimens of flowering-plants were so worthless, that it was difficult to find out, from some descriptions, to which of the specimens they were intended to apply.

In Mechanism and Applied Science book-work was satisfactorily done, but deductions and numerical applications were very imperfect. Drawing was well done, and the candidates also showed a practical acquaintance with the use of tools; but they did not sufficiently connect their mathematical with their practical knowledge.

In the previous examination or little-go, Jevons's logic was set as an alternative subject to Paley with considerable success last year. Out of forty-four candidates only six failed. In arithmetic a knowledge of decimals and the use of common sense were strikingly wanting. The gradual elevation of standard in Euclid and Algebra of late years appears to have produced beneficial results. The papers in Mechanics in the October examination (on entrance) were unsatisfactorily answered; the candidates had for the most part read treatises dealing with the subject incompletely and popularly.

The proposal to discontinue entirely the additional examination in Mathematics for Honours Candidates has been rejected by a large majority, it having been found impossible to provide any substitute which would command general assent.

Mr. M. C. Potter, Assistant Curator of the Herbarium, has been approved as a Teacher of Botany.

The Physiological class-rooms having again become seriously overcrowded, owing to the increase of the medical school, a scheme for building new class-rooms with a large lecture-room is put forward by the Museums and Lecture Rooms Syndicate. The lecture-room is to be 45 feet by 40, and 32 feet high, and is calculated to accommodate 247 students comfortably. A new class-room 80 feet long to accommodate 100 students working at one time is an important feature, and rooms will also be provided for Prof. Roy's temporary Pathological Laboratory. The estimate cost is 9000*l.*

SCIENTIFIC SERIALS

Journal of Anatomy and Physiology, January, contains:—Diseases of the reproductive organs in frogs, birds, and mammals, by J. B. Sutton (plate 8).—Oviduct in an adult male skate, by J. D. Matthews (plate 9).—On the influences of some conditions on the metamorphosis of the blow-fly, by J. Davidson.—On the sources and the excretion of carbonic acid at the liver, by J. J. Charles.—On a method of maceration, by A. M. Paterson (plate 10).—Floating kidney, by D. Hepburn.—The movements of the ulna in rotation of the fore-arm, by Thos. Dwight.—Dissection of a double monster, by A. Hill.—Relation of the alveolar form of cleft palate to the incisor teeth and the intermaxillary bones.—The dumb-bell-shaped bone in the palate of Ornithorhynchus compared with the pre-nasal bone of the pig.—The infra-orbital suture; and an additional note on the oviducts of the Greenland shark, by W. Turner.—Anatomical notes.

Quarterly Journal of Microscopical Science, January, contains:—On the significance of Kupffer's vesicle, with remarks on other questions of vertebrate morphology (plate 1), by J. T. Cunningham.—Blastopore, mesoderm, and metameric segmentation, by W. H. Caldwell (plate 2).—On the origin of the hypoblast in pelagic teleostean ova, by G. Brook.—On the presence of eyes in the shells of certain Chitonidæ, and on the structure of these organs, by H. N. Moseley (plates 4, 5, 6).—*Archerina boltoni*, nov. gen. et sp., chlorophyllogenous protozoon allied to Vampyrella, by E. Ray Lankester (plate 7).—On the apex of the root in Osmunda and Todea, by F. O. Bower (plates 7 and 8).—Correction of an error as to the morphology of *Welwitschia mirabilis*, by F. O. Bower.—E. Van Beneden's researches on the maturation and fecundation of the ovum, by J. T. Cunningham (plate 10).—On the suprarenal bodies of vertebrata, by W. F. R. Weldon (plates 11 and 12).—On the life-history of certain British heterœcismal uredines, by C. Plowright.—On the occurrence of chitin as a constituent of the cartilages of Limulus and Sepia, by W. D. Halliburton.

Journal of the Royal Microscopical Society, February, contains:—On the apparatus for differentiating the sexes in bees and wasps. An anatomical investigation into the structure of the receptaculum seminis and adjacent parts, by F. R. Cheshire (plates 1 and 2).—On the occurrence of variations in the development of a Saccharomyces, by G. F. Dowdeswell.—Notes on the life-histories of some little-known Tyroglyphidæ, by A. D. Michael (plate 3).—The usual summary of current researches in zoology, botany, and microscopy.

THE *American Naturalist*, February, contains:—On the habits of some Arvicolinæ, by E. R. Quick and A. W. Butler.—On a parasitic copepod of the clam, by R. R. Wright.—On the rudimentary hind-limb of Megaptera, and on the finger-muscles in *M. longimana* and in other whales, by J. Struthers.—The structure and development of the suspensory ligament of the fetlock in the horse, by J. D. Cunningham.—The Winooski or Wakefield marble of Vermont, by G. H. Perkins.—A botanical study of the mite-gall found in the black walnut, by Lillie J. Martin.—On the evolution of the Vertebrata, progressive and retrogressive, by E. D. Cope.

Rendiconti del Reale Istituto Lombardo, January 8.—Annual report on the work of the Institute in the various branches of science and letters during the past year, by the Secretary.—Biographical notice of Baldassare Poli, by Prof. Carlo Cantoni.

January 15.—On the secular variations in the elements of terrestrial magnetism at Venice, by Ciro Chistoni.—On a rare case of congenital malformation of the bladder, by Dr. G. Fiorani.—Extent of the diurnal oscillation of the magnet of declination at Milan in the year 1884, by Prof. G. V. Schiaparelli.—On the anatomy of the human brain, by Dr. Casimiro Mondino.—On